Health,Safety and Environmental Management in Petroleum and offshore Engineering

Prof. Dr. SrinivasanChandrasekaran

Department of Ocean Engineering

Indian Institute of Technology,Madras

Module No.#03

Lecture No. #06

Quantitative risk assessment

(Liquid release models case study – continued)

So, we have discussed about the basic problem what, we are going to solve in quantitative risk assessment method today.We are going to discussed about the liquid release models.We have discussed very briefly the case study in the last lecture number five.We are talking about the group gathering station the example is same, but we discussed in an HAZOP study in module one.There we discussed qualitative method of risk analysis using HAZOP study of the same problem.I am picking up the same example now, and I am going to do QRA -risk quantitative risk assessment for the same module where I am going to talk about liquid release models.

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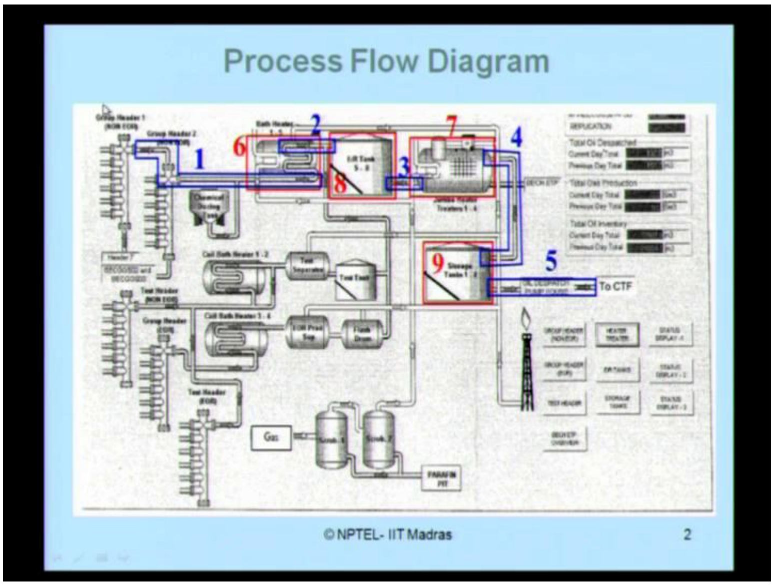

So, it is the same process and flow diagram just now we explained.This is got two categories 1,2,3,4 and 5 noted in blue color all are related to pipe segments,6,7,8,9, shown in red color all are related to vessels or tanks.So, I am going to do the risk analysis for two different levels of argument. One is the on the pipe sector other is on the vessel or the tank sector.

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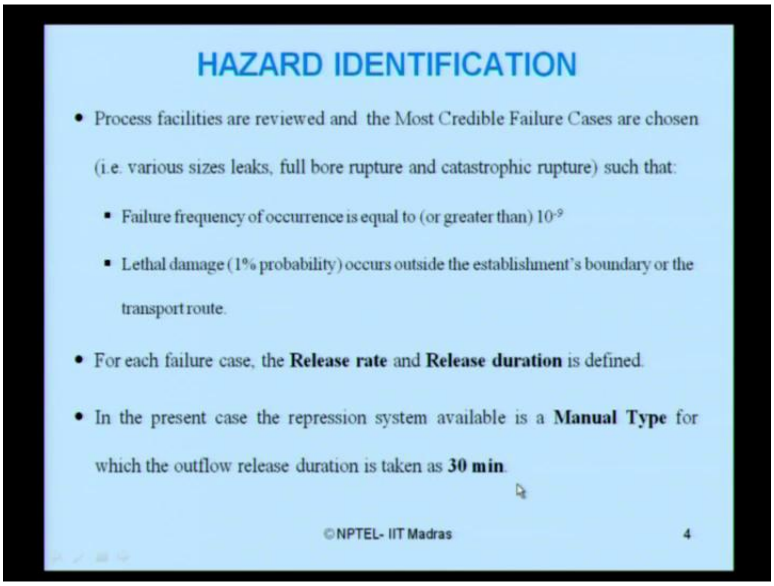

I am interested now to identify the hazards first quickly I will do that. The process facilities given, in the problem are thoroughly reviewed.After you review, you try to find out the most credible failure case.These cases are chosen, for example,look at the various size of leaks compare them with the full bore rupture and look for any catastrophic rupture possible in that failure cases.Such that, the failure frequency of occurrence is equal to or greater than 10 power minus 9.Also look for any case whichis got a lethal damage of one percent probability which is occurring outside the establishments boundary or on the transport route, because these two issues are very important which will form what we call as a most credible failure case in a given problem.

Once, you do that identification for each failure such case the release rate and the release duration.In the present example, the repression system available in the study is a manual type. On the other hand, what do you mean by this? If at all any such failure rupture occurs,the control system available to reduce that risk is actually a manual type and that takes about 30 minutes to control the rupture that is what I mean to say here.This is an example which we have considered here because this is a fact that the analysis, which I am currently doing on a group gathering station hasmanual type of repression system.

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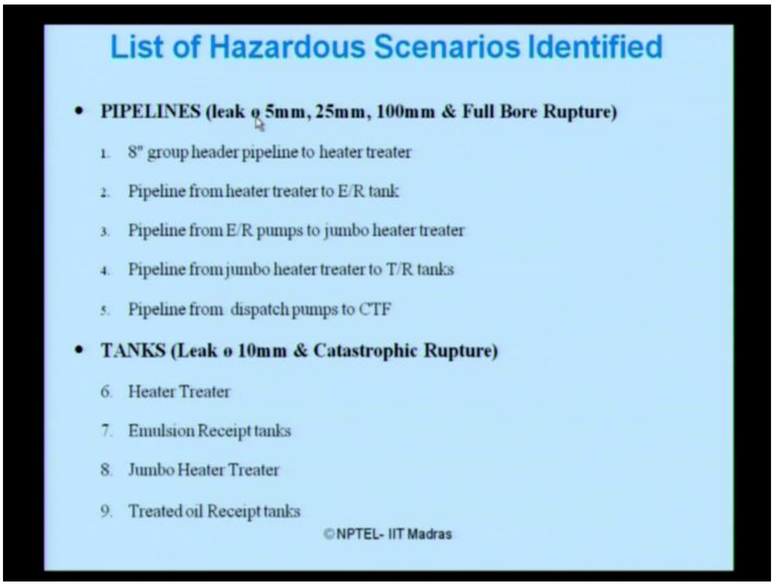

What are the lists of hazards scenarios identified by me?I have grouped them into two.One is for the pipelines and other is for the tanks.For the pipeline,I am looking for a different diameter for a leak varying from 5 millimeter,25 millimeter,100 millimeter and a full bore rupture.In that pipeline segments,I look for 8 inches group header pipeline coming to the heater treater.I look at the pipeline from heater treater to the ER tanks.Look at the pipeline segment from E R pumps to jumbo heater treater.Look at the pipelines from jumbo heater treater to TR tanks, and the pipeline from the dispatch pumps to CTF.So, I am looking for different segment of the pipeline in the process flow diagram at different units located properly.I need that pipelines we are looking for differentkinds of analysis varying from a 5 mm leak to full bore rupture is that understood.

Now, second category of hazards scenarios identified by me is basically the tank.I am looking for heater treater the E R tanks which we calls emulsion receipts tanks, the jumbo heater treaterand the treated oil receipt tanks. I look for these tanks which are 6,7,8,9 shown in red color in your process flow diagram, and 1,2,3,4,5 are pipeline segment shown as blue color in your process and flow diagram.In the tanks,I looked for either 10 mm leak, and a catastrophic rupture,for the pipeline,I look for 5 mm,25 mm,100 mm dia leaks or a full bore rupture.So, from a given process flow diagram, I identified specific segment of the problem in that segment.I subdividedthem into two basic modules one is a pipeline module failure and other is a tank module failure.

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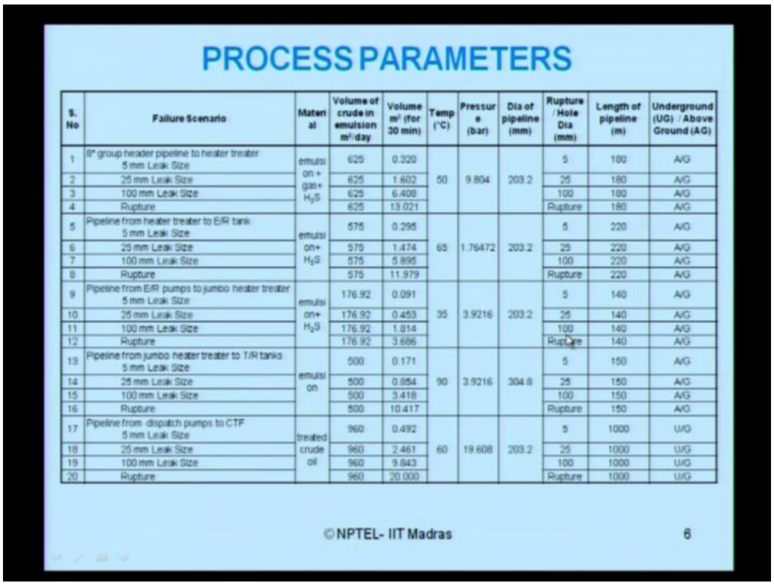

PROCESS PARAMETERS

S. No	Failure Scenario	Material	Volume of crude in emulsion m^3/day	Volume m^3 (for 30 min)	Temp (°C)	Pressure (bar)	Dia of pipeline (mm)	Rupture / Hole Dia (mm)	Length of pipeline (m)	Underground (UG) / Above Ground (AG)
1	8" group header pipeline to heater treater 5 mm Leak Size	emulsion + gas+ H_2S	625	0.320	50	9.804	203.2	5	180	A/G
2	25 mm Leak Size		625	1.602				25	180	A/G
3	100 mm Leak Size		625	6.408				100	180	A/G
4	Rupture		625	13.021				Rupture	180	A/G
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	emulsion+ H_2S	575	0.296	65	1.76472	203.2	5	220	A/G
6	25 mm Leak Size		575	1.474				25	220	A/G
7	100 mm Leak Size		575	5.896				100	220	A/G
8	Rupture		575	11.979				Rupture	220	A/G
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	emulsion+ H_2S	176.92	0.091	35	3.9216	203.2	5	140	A/G
10	25 mm Leak Size		176.92	0.453				25	140	A/G
11	100 mm Leak Size		176.92	1.814				100	140	A/G
12	Rupture		176.92	3.686				Rupture	140	A/G
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	emulsion	500	0.171	90	3.9216	304.8	5	150	A/G
14	25 mm Leak Size		500	0.854				25	150	A/G
15	100 mm Leak Size		500	3.418				100	150	A/G
16	Rupture		500	10.417				Rupture	150	A/G
17	Pipeline from dispatch pumps to CTF 5 mm Leak Size	treated crude oil	960	0.492	60	19.608	203.2	5	1000	U/G
18	25 mm Leak Size		960	2.461				25	1000	U/G
19	100 mm Leak Size		960	9.843				100	1000	U/G
20	Rupture		960	20.000				Rupture	1000	U/G

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Once,I do that,I now tabulate the process parameters of these specific scenarios.For example, I look at the scenario eight inches group header pipeline coming to the heater treater.I analyze for a 5 mm leak size.I call that a serial number one.The material being transported is an emulsion plus gas plus hydrogen sulphite.The volume of crude oil emulsion in meter cube per day for this specific transport is about 625 meter cube perday.

The volume in cubic meter per 30 minute, because that is the scenarios of duration what I am looking at why 30 minutes because in case of any rupture I am using a manual control system.It will minimum, it will take about 30 minutesfor me to control that rupture.So, I am looking for what is the volume of transfer through a 5 mm leak for about 30 minutes.

If I know,what is the volume of transfer happening in cubic meter per 24 hours,I can find out very easily. I already know the operating temperature of the specific liquid being transported is at 50 degree Celsius, and the pressure is about 9.8bar, and the diameter of the pipeline in millimeter is about 200 millimeter. The diameter is just transferring and I have said 18 just converting that to millimeter,I got a fractionhere anyway.I am looking for a rupture hole diameter of 520,500 and the full rupture that is what I am looking at.

So, I am looking for four failure scenarios one, two, three, four.For eight inches pipeline going to the pipe heater treater, the length of the pipeline is about 180 meters.And the pipeline is also located whether it is above groundor over ground or underground.All these pipelines are above ground.Then I look for the second scenarios which is the pipeline transferring from heater treater to emulsion recipient tanks.I look for again 5 mm 25 mm,100 mm and rupture total rupture leak.I say the numbers are 5,6,7,8 andsoon.The emulsion is again same, the volume is 575 in this case. The volume of cubic meter per 30 minutes is again calculated and operating temperature isslightly higher.The pressure is again slightly lower.

The diameters again eight inches as I am looking for and I am looking for all the four scenarios.The length of the pipeline is about two hundred twenty meters and the pipeline is located above ground second.The thirdly pipeline from emulsion recipient tank to the jumbo heater treater is having a volume of one seventy six point nine two cubic meter per day.The volume of cubic meter in thirtyminute is about this because, I am looking for a thirty minutes scenario of leak.The operating temperature is now reduced to 35 degree Celsius.

The pressure is now slightly increased from one point seven bar to three point nine bar.The diameter of pipeline is again eight inches.The rupture I am analyzing for all the four cases.The length of the pipeline is about hundred and forty meters which i am looking now.And the pipeline is located above ground.The fourth scenario is from the jumbo heater treater to the T R tanks.The quantity is about five hundred cubic meter per day.

The operating temperature is about ninety degree Celsius now the pressure is maintained same where as the diameter slightly increase is about three hundred four mm now.I am looking for all the four scenarios the length of the pipeline is marginally different this is about hundred and fifty meters and the pipeline is located above ground.The last segment of the analysis of the pipeline is from the dispatch pumps to the CTF.It is actually carrying the treated crude oil now the volume is about nine sixty cubic meter a day.And operating temperature is about a sixty degree Celsius.And the pressure is relatively very, very high is about 20 bar.

And the diameter doing that is about 200 mm which is eight inches diameter.I am looking for the four scenarios the length of the pipe present seriously long because this is now a kilometer long now.And this pipeline is having another catch this pipeline is buried in soil is an underground pipeline.So, from a given process and flow diagram I basically group what are the basic scenarios I am looking for.What are those leak ruptures, I am looking for.And what are those data's which are important for me to compute the risk parameters.

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S.No	Scenarios	Material	Volume of crude in the emulsion (m^3)	Pressure (bar)	Temperature (°C)	Dia (m)	length / height (m)	Leak Dia (mm)
21	Heater treater 10 mm Leak Size	emulsion + gas+ H_2S	5.75	1.9608	65	2.3	6.2	10
22	Catastrophic Rupture		5.75					Catastrophic Rupture
23	E/R tanks 10 mm Leak Size	emulsion+ H_2S	294.87	atm	35	11.5	10	10
24	Catastrophic Rupture		294.87					Catastrophic Rupture
25	Jumbo heater treater 10 mm Leak Size	emulsion+ H_2S	58.97	4.4118	90	3.9	19.4	10
26	Catastrophic Rupture		58.97					Catastrophic Rupture
27	T/R tanks 10 mm Leak Size	emulsion	450	atm	60	8	10	10
28	Catastrophic Rupture		450					Catastrophic Rupture

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Similarly, if you look at the tank sector the heater treater can have an ten m m leak or a catastrophic rupture.I am doing these two analyses for all the tanks of heater treater,E R tanks, jumbo heater treater, and T R tanks.You can see this scenarioare common for all the four tanks which are labeled as dashed six, seven, eight, and nine in your process and flow diagram.Don't look at this number, this number is actually serial number of my risk parameters being assists. Now, material being stored in the tanks as emulsion plus gas plus hydrogen sulphite.The volume they are handling is about 5.75 cubic meter per day.The pressure is about 1.96bar at a temperature of 60 degree celcius.The diameter is about 2.3 meter that the diameter of heater treater tank.The length and height of the tank is about 6.2 meter.The leak diameter what, I am looking at is ten mm dia leak or a catastrophic rupture.

I think you appreciate from the previous lecture.If you want really look at the liquid dispersion modeling of risk analysis, you must categorically say, what kind of leak rupture you are looking at that is how you calculate what we call as chemical exposure index.I am looking for all the four tanks heater treater,E R tank,jumbo heater treaterand T R tanks.

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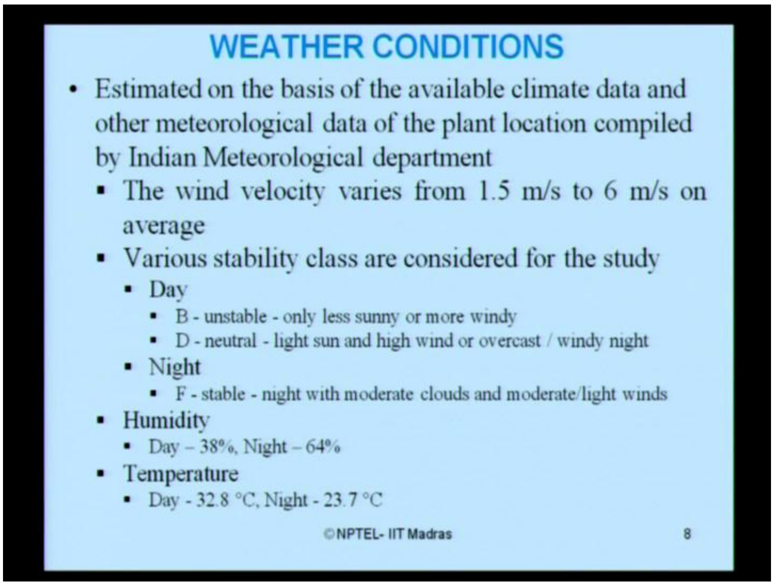

Once, I do that subsequently, I also look at the different weather conditions which I am now considering my risk analysis.As you all understand the quantitative risk assessment also depends on the weather condition at which you are doing the analysis, and the weather condition at which the risk actually occurs in the plants.Now, the weather conditions are actually estimated on the base of the available climatic data.And other meteorological data of the plant location and they are generally available with Indian meteorological department, and every country has their own meteorological department which can give you the climatic data on a geographic location of the plant where you are conducting study.

In my case, the wind velocity is considered to vary from one point five meter per second to six meter per second on average.I am also looking for different stability classthey are required in the analysis using software.I call the b class as unstable class, it means only less sunny or more windy weather. I call that d class as neutral class, where there is a light sun availability and high wind or overcast windy night.During the night,I say the class f stable, becauseit is the night class with moderate clouds and moderates light winds.I considered the humidity during the day as 38 percent and during the night as sixty four percent for this problem.I am considering an average operating temperature as 32.8 degree during day time and 23.7 degree Celsius during night time.These are all different weather conditions which will be employing in may risk analysis study subsequently.

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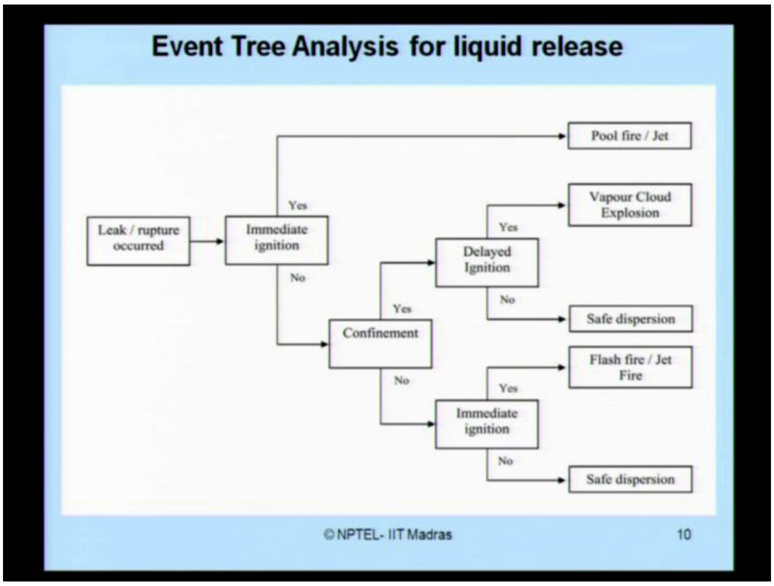

Now, I do what is called consequence analysis.I am interested in doing what i am calling as event tree analysis for liquid release.Care we look at this flow chart, it is very, very interesting it is a basically an event tree analysis we carried out for a liquid release for this problem.Look at the leak or a rupture occurred at any particular point, it may be in the pipeline it may be in the vessel.If that rupture is possible to have an immediate ignition, if that possibility is there, then you can always say you can result in what we call as a pool fire or a jet fire.So, all your preventingmeasures should be related to controlling the jet fire which can instantaneously occur.Why, because whenever any leak occurs from the pipeline or from the tank.If that has a possibility of immediate ignition then it may result in pool fire.

Now, if there is no probability of immediate ignition for that particular chemical or the liquid being released, then checked whether is it confined within specific area.This confinementif it is possible then is it possible to have delayed ignition can you do a delayed ignition.If the delayed ignition is possible, then it may result in what we call as vapor cloud explosion.If the delayed ignition is not possible, then it can have what we call as a safe dispersion.If on the other hand,your liquid being ruptured is actually not confined and it has an immediate ignition.Then it may again set what we call as a jet fire or a flash fire.If that immediate ignition is not possible, then we can say the liquid is ready for safe dispersion.

So, it is a very simple event tree analysis which is also one of the method of risk analysis incidentally.It can tell you from a simple flow chart of this kind it can tell you what kind of exit will be there as a consequence of your accident.It can cause either a pool fireit can cause a jet fire it can cause vapor cloud explosion.Or it can be safe for dispersion it can cause a flash fire or it can safe for dispersion.When these situation are occurring or when they are possible that can be easily seen from a simple analysis what we call as event tree analysis.

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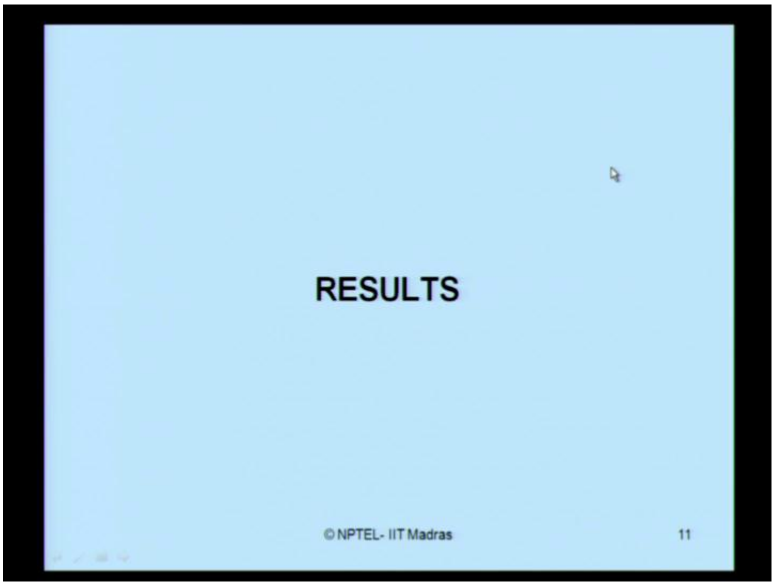

Once, I do that I input these data in the software because these all are very cumbersome data to do a risk analysis.Iusespecific software,I input these data, let us look at the results and argue and discuss on the result further.

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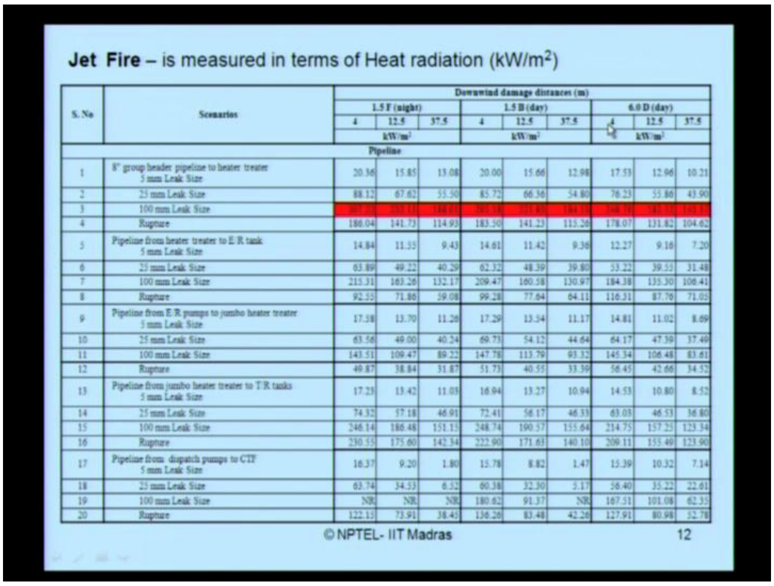

Jet Fire – is measured in terms of Heat radiation (kW/m^2)

S. No	Scenarios	Downwind damage distances (m)								
		1.5 F (night)			1.5 B (day)			6.0 D (day)		
		4	12.5	37.5	4	12.5	37.5	4	12.5	37.5
		kW/m^2			kW/m^2			kW/m^2		
	Pipeline									
1	8" group header pipeline to heater treater 5 mm Leak Size	20.36	15.85	13.08	20.00	15.66	12.98	17.53	12.96	10.21
2	25 mm Leak Size	88.12	67.62	55.50	85.72	66.36	54.80	76.23	55.86	43.90
3	100 mm Leak Size	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Rupture	186.04	141.73	114.93	183.50	141.23	115.26	178.07	131.82	104.62
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	14.84	11.55	9.43	14.61	11.42	9.36	12.27	9.16	7.20
6	25 mm Leak Size	63.89	49.22	40.29	62.32	48.39	39.80	53.22	39.55	31.48
7	100 mm Leak Size	215.31	163.26	132.17	209.47	160.58	130.97	184.38	135.30	106.41
8	Rupture	92.55	71.86	59.08	99.28	77.64	64.11	116.31	87.76	71.05
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	17.38	13.70	11.26	17.29	13.54	11.17	14.81	11.02	8.69
10	25 mm Leak Size	63.56	49.00	40.24	69.73	54.12	44.64	64.17	47.39	37.49
11	100 mm Leak Size	143.51	109.47	89.22	147.78	113.79	93.32	145.34	106.48	83.61
12	Rupture	49.87	38.84	31.87	51.73	40.55	33.39	56.45	42.66	34.52
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	17.23	13.42	11.03	16.94	13.27	10.94	14.53	10.80	8.52
14	25 mm Leak Size	74.32	57.18	46.91	72.41	56.17	46.33	63.03	46.53	36.80
15	100 mm Leak Size	246.14	186.48	151.15	248.74	190.57	155.64	214.75	157.25	123.34
16	Rupture	230.55	175.60	142.34	222.90	171.63	140.10	209.11	155.49	123.90
17	Pipeline from dispatch pumps to CTF 5 mm Leak Size	16.37	9.20	1.80	15.78	8.82	1.47	15.39	10.32	7.14
18	25 mm Leak Size	63.74	34.53	6.52	60.38	32.30	5.17	56.40	35.22	22.61
19	100 mm Leak Size	NR	NR	NR	180.62	91.37	NR	167.51	101.08	62.35
20	Rupture	122.15	73.91	38.45	136.26	83.48	42.26	127.91	80.98	52.78

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For example, let us say I am looking for one specific result, which is a jet fire.Jet fire is measured in terms of heat radiation, which is given as kilowatt per square meter area.And I look for all the scenarios of eight inches pipeline, eight inches group header pipeline to heater treater.Pipeline from heater treater to E R tank, pipeline from E R pumps to jumbo heater treater, pipeline from jumbo heater treater to TR tanks, and pipeline from dispatch to CTF.In all these reasons of one, two, three, four, and five shown as a blue color in a process flow diagram.I am analyzing for all four scenarios of five mm leak, twenty five mm leak ,hundred mm leak and rupture.

Now, I am looking for downward damage distances in meters for different stability class.That is f in the night b in the day and d in the day.And I also look for different radiation levels of four twelve point five and thirty seven point five.These all are different levels of radiation which can be sustained which cannot be sustained in kilowatt per square meter.For example, the radiation level is about 4 kilowatt per square meter can go for a longer distance and can be sustainable. If the radiation level is about 37.5 kilowattper square meter, it is un-tolerable therefore, that having more risk level.

And if that happens, in night at one point five f it happens in day at one point five b that is the suitability class it can happen in night and the day at six d again stability class.If you look at this and do the analysis in the software, I get a result of this tabulated value here.In that tabulated value, I look at this red level of hundred mm leak.This is identified as a very undesirable level of consequence which I get from the jet fire.You may wonder how I arrive as a specific red band, I will come to that at the end of the presentation.

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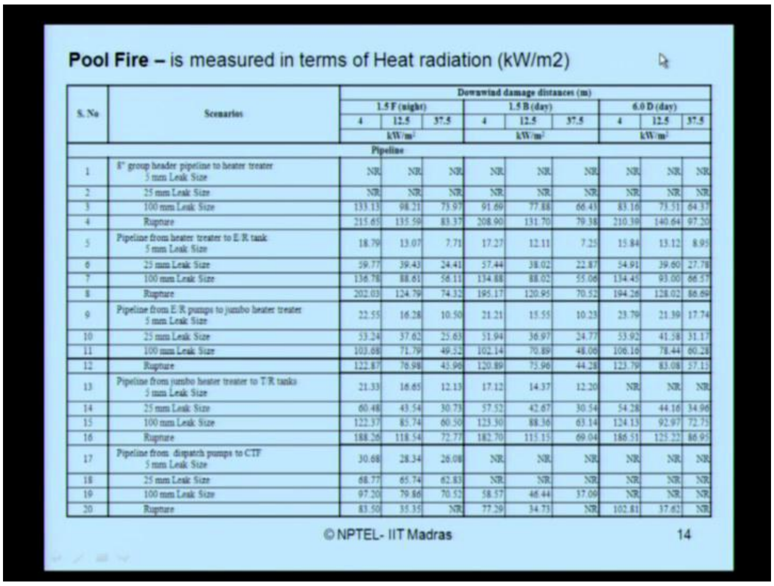

Pool Fire – is measured in terms of Heat radiation (kW/m2)

S. No	Scenarios	Downwind damage distances (m)								
		1.5 F (night)			1.5 B (day)			6.0 D (day)		
		4	12.5	37.5	4	12.5	37.5	4	12.5	37.5
		kW/m²			kW/m²			kW/m²		
Pipeline										
1	8" group header pipeline to heater treater 5 mm Leak Size	NR	NR	NR	NR	NR	NR	NR	NR	NR
2	25 mm Leak Size	NR	NR	NR	NR	NR	NR	NR	NR	NR
3	100 mm Leak Size	133.13	98.21	73.97	91.69	77.88	66.43	83.16	73.51	64.37
4	Rupture	215.65	135.59	83.37	208.90	131.70	79.38	210.39	140.64	97.20
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	18.79	13.07	7.71	17.27	12.11	7.25	15.84	13.12	8.95
6	25 mm Leak Size	59.77	39.43	24.41	57.44	38.02	22.87	54.91	39.60	27.78
7	100 mm Leak Size	136.78	88.61	56.11	134.88	88.02	55.06	134.45	93.00	66.57
8	Rupture	202.03	124.79	74.32	195.17	120.95	70.52	194.26	128.02	86.69
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	22.55	16.28	10.50	21.21	15.55	10.23	23.79	21.39	17.74
10	25 mm Leak Size	53.24	37.62	25.63	51.94	36.97	24.77	53.92	41.58	31.17
11	100 mm Leak Size	103.68	71.79	49.52	102.14	70.89	48.06	106.16	78.44	60.28
12	Rupture	122.87	76.98	45.96	120.89	75.96	44.28	123.79	83.08	57.13
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	21.33	16.65	12.13	17.12	14.37	12.20	NR	NR	NR
14	25 mm Leak Size	60.48	43.54	30.73	57.52	42.67	30.54	54.28	44.16	34.96
15	100 mm Leak Size	122.37	85.74	60.50	123.30	88.36	63.14	124.13	92.97	72.75
16	Rupture	188.26	118.54	72.77	182.70	115.15	69.04	186.51	125.22	86.95
17	Pipeline from dispatch pumps to CTF 5 mm Leak Size	30.68	28.34	26.08	NR	NR	NR	NR	NR	NR
18	25 mm Leak Size	68.77	65.74	62.83	NR	NR	NR	NR	NR	NR
19	100 mm Leak Size	97.20	79.86	70.52	58.57	46.44	37.09	NR	NR	NR
20	Rupture	83.50	35.35	NR	77.29	34.73	NR	102.81	37.62	NR

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Similarly, I look at for the tanks heater treater, ER tanks, jumbo heater treater, and T R tanks.I look at for scenarios of 10 mm leak or a catastrophic rupture in all of them.So, basically this is considered as number six in your process flow diagram.So, number six, number seven, number eight, and number nine, which is shown in blue color in your PFD.And in that I am looking for both the kinds of possibilities of 10 mm leak and a catastrophic rupture.And I have again look for downwind damage distances for different stability class as it did for the pipeline segment and we look for the values obtained from the software.

And I am seeing there are no red band available in thissoftware can also compare these values with respect to the pipelines leak scenarios. They were all basically the value related to from 14 to 33 or 35, whereas in the earlier case the values havegone as high as 300, which is become a red band.Now, I look at the second scenarios which is can be a pool fire.You may wonder how a pool fire can be caused we have already given you the equation inthe third module lecture one and two.

When a liquid can become a pool fire, when a liquid can cause a jet fire, when a liquid can simply become a safe dispersion etcetera,by giving two examples.Kindly look at them back again.Ascertainthe conditions for you liquid to become a pool fire, if it becomesa pool fire again for the pipeline segment and for the tank segment.I have done the analysis using the software, I have got the results again, I do not have a band values here.

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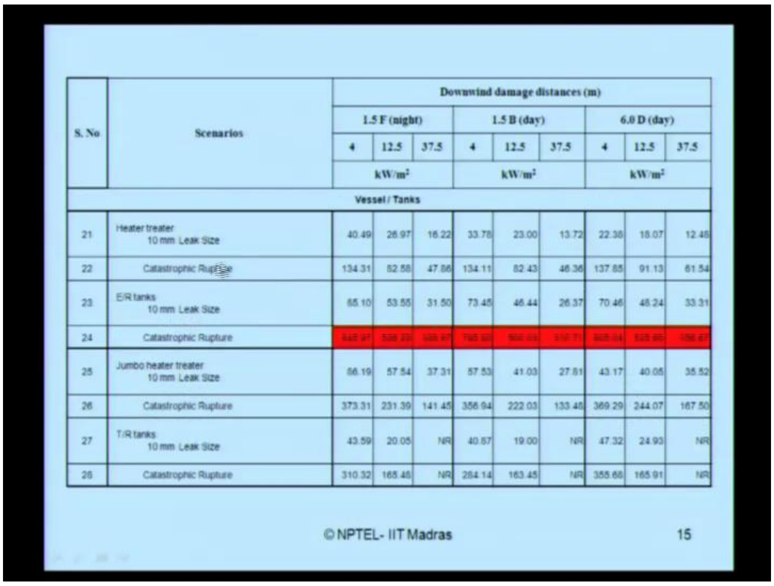

S. No	Scenarios	Downwind damage distances (m)								
		1.5 F (night)			1.5 B (day)			6.0 D (day)		
		4	12.5	37.5	4	12.5	37.5	4	12.5	37.5
		kW/m^2			kW/m^2			kW/m^2		
Vessel / Tanks										
21	Heater treater 10 mm Leak Size	40.49	26.97	16.22	33.78	23.00	13.72	22.38	18.07	12.48
22	Catastrophic Rupture	134.31	82.58	47.86	134.11	82.43	46.36	137.85	91.13	61.54
23	E/R tanks 10 mm Leak Size	85.10	53.55	31.50	73.45	46.44	26.37	70.46	48.24	33.31
24	Catastrophic Rupture	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	Jumbo heater treater 10 mm Leak Size	86.19	57.54	37.31	57.53	41.03	27.81	43.17	40.05	35.52
26	Catastrophic Rupture	373.31	231.39	141.45	356.94	222.03	133.48	369.29	244.07	167.50
27	T/R tanks 10 mm Leak Size	43.59	20.05	NR	40.87	19.00	NR	47.32	24.93	NR
28	Catastrophic Rupture	310.32	165.48	NR	284.14	163.45	NR	355.66	165.91	NR

Unfortunately, when we look for the catastrophic rupture on an E R tank for a pool fire, I get the very, very high value this depends upon the frequency and consequence which are input in the risk analysis software and I get the numbers as high as eight and fifty. So, that becomes a red band here.Similarly, I look for the third scenarios whichI called as an explosion this is generally measured in terms of over pressure as bar.I look for the value of downwind damage distances and there are some standard threshold value beyond which it is considered as very high.

So, if you look at the pipeline segment again 100 mm leak size as a higher undesirable value varying from about let us say 450 to as high as 820.So, it gets a red band remaining values do not get red band on the pipeline segment.Subsequently we also did this for the tank segments and fortunately I do not have any red band in the tank segment at all, after doing these kinds of analysis for jet fire pool fire etcetera.Now I start doing what we call as frequency analysis.

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S.No	Scenarios	pipeline Length (m)	Failure frequency (per m per annum)	Total Basic failure frequency (per annum)	Blocking System	NRV	EFCV	Fire protection system	Calculated failure frequency (per annum)
1	8" group header pipeline to heater treater 5 mm Leak Size	180	1.70E-05	3.06E-03	0.99	0.06	0.99	0.5	9.00E-05
2	25 mm Leak Size	180	7.40E-06	1.33E-03	0.99	0.06	0.99	0.5	3.92E-05
3	100 mm Leak Size	180	7.60E-06	1.37E-03	0.99	0.06	0.99	0.5	4.02E-05
4	Rupture	180	5.90E-06	1.06E-03	0.99	0.06	0.99	0.5	3.12E-05
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	220	1.70E-05	3.74E-03	0.99	0.99	0.99	0.5	1.81E-03
6	25 mm Leak Size	220	7.40E-06	1.63E-03	0.99	0.99	0.99	0.5	7.90E-04
7	100 mm Leak Size	220	7.60E-06	1.67E-03	0.99	0.99	0.99	0.5	8.11E-04
8	Rupture	220	5.90E-06	1.30E-03	0.99	0.99	0.99	0.5	6.30E-04
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	140	1.70E-05	2.38E-03	0.99	0.06	0.99	0.5	7.00E-05
10	25 mm Leak Size	140	7.40E-06	1.04E-03	0.99	0.06	0.99	0.5	3.05E-05
11	100 mm Leak Size	140	7.60E-06	1.06E-03	0.99	0.06	0.99	0.5	3.13E-05
12	Rupture	140	5.90E-06	8.26E-04	0.99	0.06	0.99	0.5	2.43E-05
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	150	1.60E-05	2.40E-03	0.99	0.99	0.99	0.5	1.16E-03
14	25 mm Leak Size	150	6.70E-06	1.01E-03	0.99	0.99	0.99	0.5	4.88E-04
15	100 mm Leak Size	150	1.40E-06	2.10E-04	0.99	0.99	0.99	0.5	1.02E-04
16	Rupture	150	5.90E-06	8.85E-04	0.99	0.99	0.99	0.5	4.29E-04
17	Pipeline from dispatch pumps to CTF 5 mm Leak Size	1000	1.70E-05	1.70E-02	0.99	0.06	0.99	0.5	5.00E-04
18	25 mm Leak Size	1000	7.40E-06	7.40E-03	0.99	0.06	0.99	0.5	2.18E-04
19	100 mm Leak Size	1000	7.60E-06	7.60E-03	0.99	0.06	0.99	0.5	2.23E-04
20	Rupture	1000	5.90E-06	5.90E-03	0.99	0.06	0.99	0.5	1.73E-04

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I am looking for the frequency failure calculations how do we get that.For example, look atthe pipeline segments.Let say I consider a pipeline group header pipeline going to the heater treater.I am looking for all the four scenarios 5 mm,25 mm,100 mm and the catastrophic whole point rupture.We already know the pipeline of length of 180 meters.The failure frequency per meter per annum which has been taken as a statistical data based on experience similar plants is given here.So, what is it mean if you considered the yester data you get an average failure frequency of one point seven ten power minus five per meter per annum.

Now, what is the total basic failure.I can simply multiply the frequency per meter per annum into length of the pipe.I will get the total basic failure in frequency per annum. So, the parameter of the length of the pipe is now eliminatedfrom this column to this column.So, this is nothingbut,the product of this multiplied by the length in meters.I will get this value now the blocking system is being given a number which is varying from zero to one and I have selected this number as 0.99.If this pipe segment has any non return valve and any other emergency situation to attack or to counter act the problem,I have given the specificweightage of these two as 0.06 and 0.99.

If the segment as any fire protection system, I give a credit to that and ultimately,I calculate the frequency per annum as 9 into 10 to power minus 5.So, that is the frequency for example, the frequency per meter is about 1.7 into 10power minus

5.Imultiply this for the whole length,I get very high three point zero six ten power minus three.Considering, the safety factors present in the system, I ultimately compute the failure frequency as nine ten power minus five.

Remember that, this is a computed failure frequency this is the frequency failure only taken from a previous experience of any such plant.So, this failure frequency given due weightage to existing system and safe guard available, I get what we call calculated failure frequency from the software directly.Now, I get this frequency for different type and segments in the PFD for different scenarios identified by me like 5 mm leak,25 mm leak,100 mm leak and rupture.we always see here, if you look for a whole pipe rupture the calculated frequency is relatively different from that of what you take for the 5 mm leak.And that is true for all the pipeline segment.

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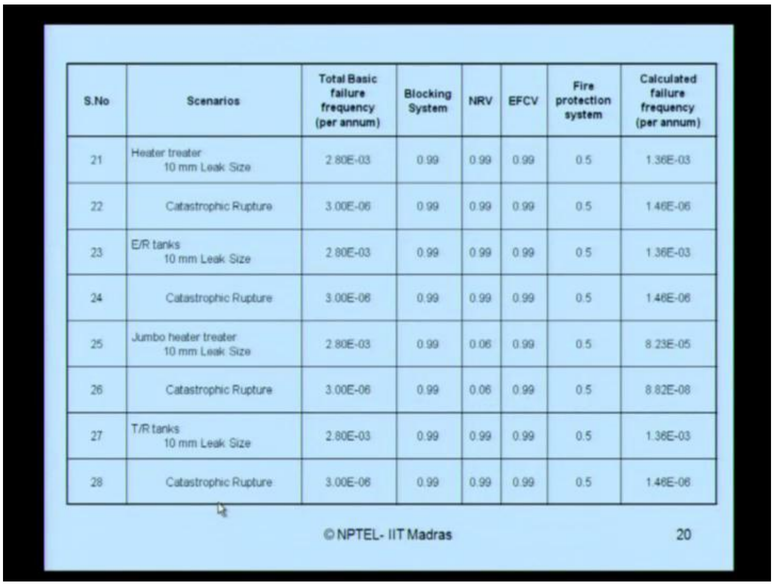

S.No	Scenarios	Total Basic failure frequency (per annum)	Blocking System	NRV	EFCV	Fire protection system	Calculated failure frequency (per annum)
21	Heater treater 10 mm Leak Size	2.80E-03	0.99	0.99	0.99	0.5	1.36E-03
22	Catastrophic Rupture	3.00E-06	0.99	0.99	0.99	0.5	1.46E-06
23	E/R tanks 10 mm Leak Size	2.80E-03	0.99	0.99	0.99	0.5	1.36E-03
24	Catastrophic Rupture	3.00E-06	0.99	0.99	0.99	0.5	1.46E-06
25	Jumbo heater treater 10 mm Leak Size	2.80E-03	0.99	0.06	0.99	0.5	8.23E-05
26	Catastrophic Rupture	3.00E-06	0.99	0.06	0.99	0.5	8.82E-08
27	T/R tanks 10 mm Leak Size	2.80E-03	0.99	0.99	0.99	0.5	1.36E-03
28	Catastrophic Rupture	3.00E-06	0.99	0.99	0.99	0.5	1.46E-06

Similarly, I have also done for the tank segment that is heater treater,E R tanks, jumbo heater treater, and T R tanks for both the scenarios of 10 mm leak and catastrophic rupture.The total basic failure frequency based upon previous experience of similar plant is available here.The blocking system is been given some weightage. The efficiency of the controlling system has been given some weightage.Based on these,I compute the calculated failure frequency per annum as one point three six ten power minus three for a 10 mm size leak of a heater treater.And I can do that all the vessels of tanks for different scenarios and soon and soforth.

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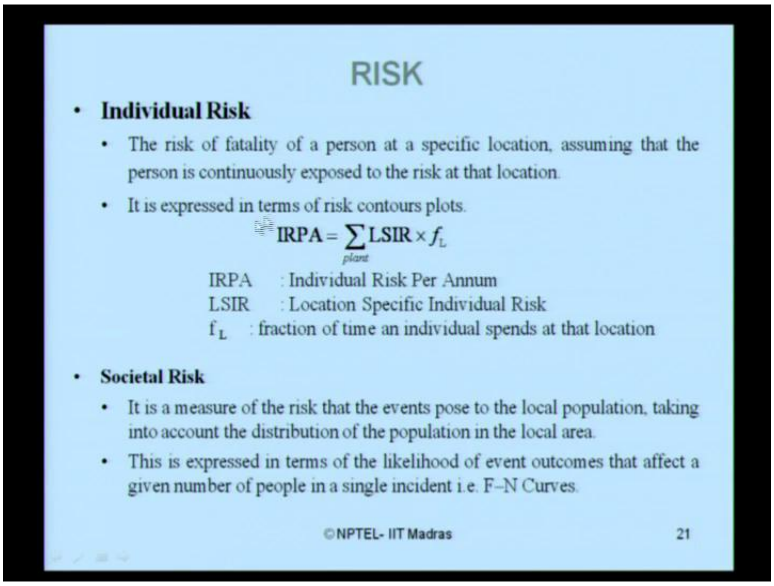

Once, I do that now estimate, what I called as an individual risk and a societal risk.How do I get that the risk of fatality of a person at a specific location assuming that the personis continuously exposed to the risk at that location that is the basic assumption for individual risk is expressed in terms of risk contours plots.

Ladies and gentlemen, I told you most of the software's will give you the output of the risk analysis in a graphical format as well as. So, what we call as risk contours.It is given by a simple expression here IRPA is summation of LSIR for the whole plant multiplied by f L.Whereas IRPA is what, I call as individual risk per annum which Iam interested to calculate. LSIR is a location specific individual risk. So, the plant can have risk at different locations.

Therefore, we sum up this for the whole scenario of the plant and each location specific individual risk as a fraction of time of an individual spends at that location for example.Your plant has different location a, b, c, d, e an employeemay spendin working hoursor wait he spends four hours location a.And about 30 minute in location e.So, each location specific has a fraction of time what he spends on that location.

I multiply that with the location specific individual risk available at that location and I do this for whole plant I get what is called individual risk per annum.I can also compute the societal risk.Actually it is a measure of risk that the events post to the local population taking into account the distribution of the population in the local area.This is generally given in terms of F-N curves.Where,F-N is basically expanded as the curve between the likelihood of the events outcomes that affects a given number in a single incident.

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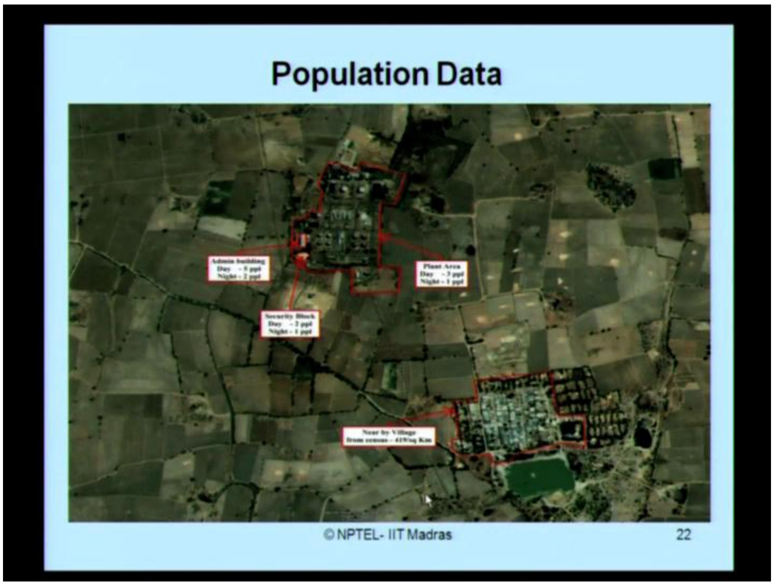

Now, I have a population data in the specific GGS, where it is situated I am masking the specific location without identifying the name of the plant.So, I have a data which have taken froma geographical data of specific plant.This is the plant which I am looking for this isanother segment of the plant where the nearby village, which is close in a visionary of this plant.I am looking for GGS group gathering station located in this area, I am looking for effect or theconsequence of this leak if at all it occurs in the neighbour village as well as this the plant data is been available here in different building.The security block the does not shade a building the plant area and the nearby village.

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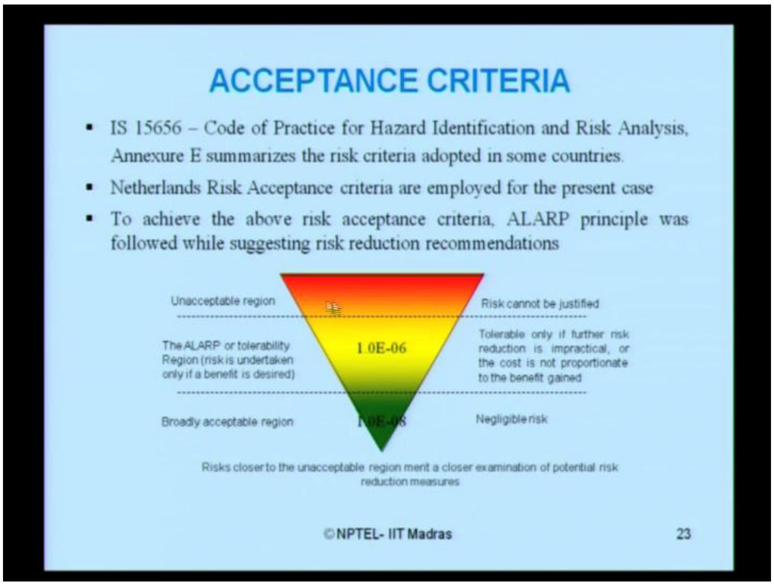

This figure is very interestingly remembered by you.We now call after computing risk whether the risk is acceptable to us.We call thisas acceptable criteria.IS15656 which actually a code of practice for hazard identification risk analysis.The annexure e in this code summarizes the risk criteria adopted in some countries.You can look at this as a reference book for computing or let saycalculating the risk acceptance levels for your problem.Alternatively you can also look at the Netherlands risk acceptance criteria.

To achieve the above, risk acceptance criteria ALARPprinciple was followed in this specific case study.We have already seen the specific triangle.There are red region yellow region and green region.Now, what is interesting here is if your risk calculated in the previous slide from the software.Falls in the band of one ten power minus six we say that it is an ALARP region.If the risk falls in the value of one point zero ten to power minus eight or lower than that then we can say it is broadly acceptable region.

If the risk is much higher than one point zero ten power minus six.For example,let us say one ten to power minus five andsoon then the risk is on theunacceptable region.So, you have calculated risk per every event on thepipeline segment every event on the tank segment for different scenarios.Now, pick up only those numbers and see where these number fifteen in the ALARPtriangle.I have done that.

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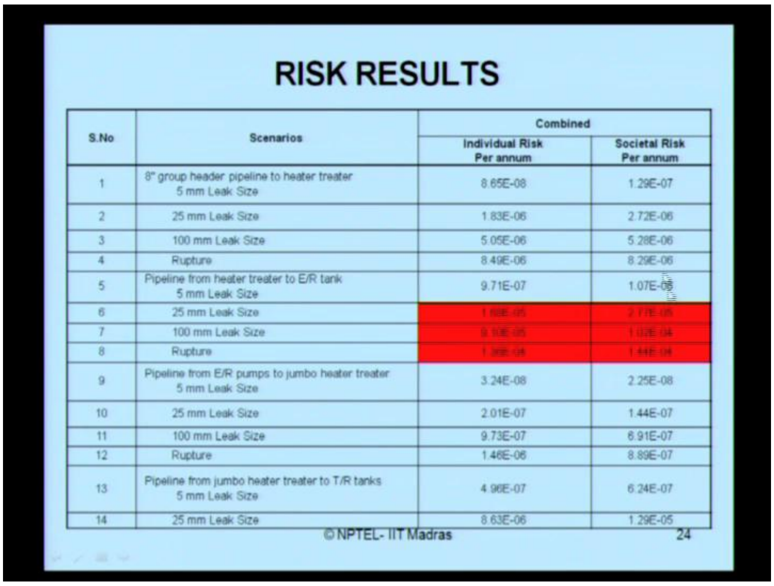

RISK RESULTS

S.No	Scenarios	Combined	
		Individual Risk Per annum	Societal Risk Per annum
1	8" group header pipeline to heater treater 5 mm Leak Size	8.65E-08	1.29E-07
2	25 mm Leak Size	1.83E-06	2.72E-06
3	100 mm Leak Size	5.05E-06	5.28E-06
4	Rupture	8.49E-06	8.29E-06
5	Pipeline from heater treater to E/R tank 5 mm Leak Size	9.71E-07	1.07E-0[illegible]
6	25 mm Leak Size	[illegible]	[illegible]
7	100 mm Leak Size	[illegible]	[illegible]
8	Rupture	[illegible]	[illegible]
9	Pipeline from E/R pumps to jumbo heater treater 5 mm Leak Size	3.24E-08	2.25E-08
10	25 mm Leak Size	2.01E-07	1.44E-07
11	100 mm Leak Size	9.73E-07	6.91E-07
12	Rupture	1.46E-06	8.89E-07
13	Pipeline from jumbo heater treater to T/R tanks 5 mm Leak Size	4.96E-07	6.24E-07
14	25 mm Leak Size	8.63E-06	1.29E-05

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For example, if you look at the pipeline segment of a, b, c, d andsoon for different scenarios.I see that these values of ten to power minus seven minus six are in a different region whereas ten power minus five and minus four fall in the red region which an unacceptable region.So, what I did is after I get this result, I summarize them for individual risk and socieal risk.Then I check whether these number exceed the value given in ALARPtriangle.Those values exceeded given in ALARPtrianglehas been highlighted in red here.And the corresponding scenario I have been carefully looked at.

For example the pipeline segment which is carrying the fluid from heater treater to E Rtank.If it ruptures at 25 mm leak then the risk exposure level to the individual will be unacceptable.To the society also will be unacceptable that is how you will interpret results what I am showing you in the present slide.

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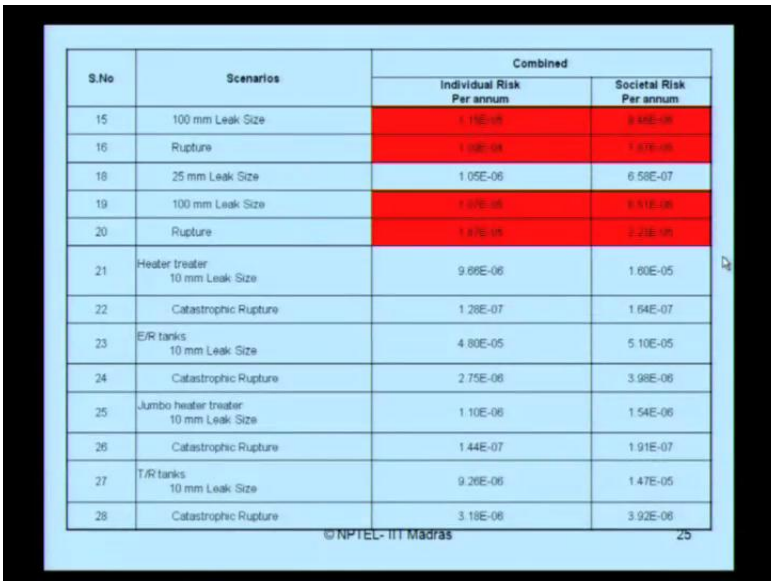

S.No	Scenarios	Combined	
		Individual Risk Per annum	Societal Risk Per annum
15	100 mm Leak Size	[illegible]	[illegible]
16	Rupture	[illegible]	[illegible]
18	25 mm Leak Size	1.05E-06	6.58E-07
19	100 mm Leak Size	[illegible]	[illegible]
20	Rupture	[illegible]	[illegible]
21	Heater treater 10 mm Leak Size	9.66E-06	1.60E-05
22	Catastrophic Rupture	1.28E-07	1.64E-07
23	E/R tanks 10 mm Leak Size	4.80E-05	5.10E-05
24	Catastrophic Rupture	2.75E-06	3.98E-06
25	Jumbo heater treater 10 mm Leak Size	1.10E-06	1.54E-06
26	Catastrophic Rupture	1.44E-07	1.91E-07
27	T/R tanks 10 mm Leak Size	9.26E-06	1.47E-05
28	Catastrophic Rupture	3.18E-06	3.92E-06

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I look at that for other scenarios, I look at that for different vessels.You can see some of the risk values are falling on the red region in the ALARPtriangle which is unacceptable risk by a specific standard.In this current example, I am following the Indian standard and incidentally, if you look at the rupture on the vessel or the tank segments.For all the four scenarios may be a 10 mm leak or catastrophicrupture all these risk level computed are very much falling on either in the ALARPregion or on the safe region.So, ladies and gentleman, starting from a process and flow diagram. You can easily estimate actually the risk as a number which will tell you, whether that risk if at all a rupture occurs is acceptable to an individual or to a society in per annum basis.

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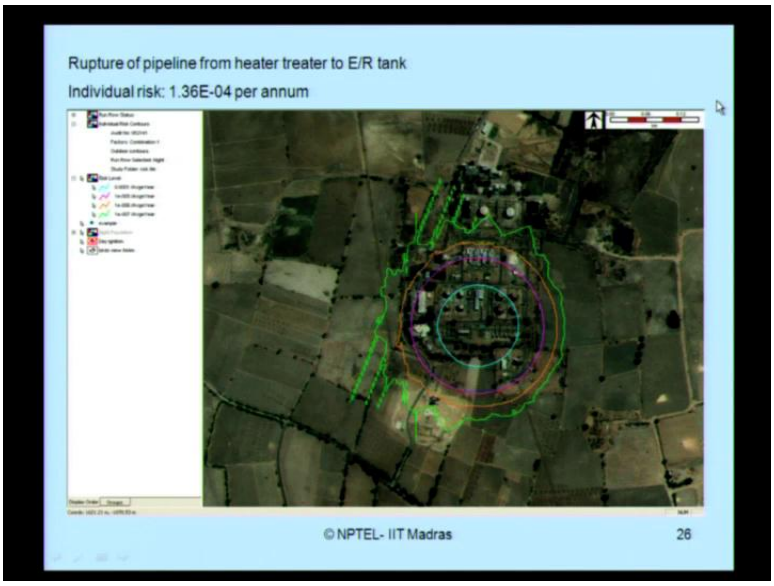

As I said ultimately the risk should be given as a risk contours in a graphical format.This is the solution what,I am getting here in the graphical format.The individual risk what I get here is about one point three six ten power minus four per annum which is shown in the blue color here.And this is an acceptable region this is an ALARPregion and that is a safe region.So, you get a basically contours and this is actually epicenterof the problem where the plant or the GGS is located.This is scenario for the pipeline rupture from heater treater to E R tank which is already in the red region.

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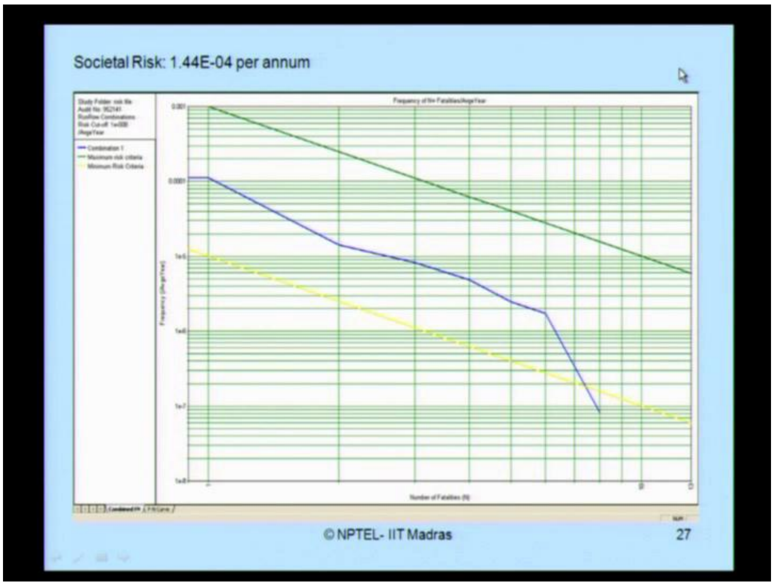

If I look at the societal risk, I used expression that as an F-N curve.F is the number of fatalities plotted in the x axis and n is the frequency plotted in y axis an average per year.And this is number n that is why we call as F-N curve.And you look at the scenario the societal risk what I get is one point four four ten power minus four per annum.The green line what you see here is a combination of both.Is the maximum risk criteria and the minimum risk criteria is given in blue color.So, what I am getting here is a combination of these two and my problem is falling somewhere here.Therefore there is no societal risk except for one rupture which is on the pipeline segment as discussed.

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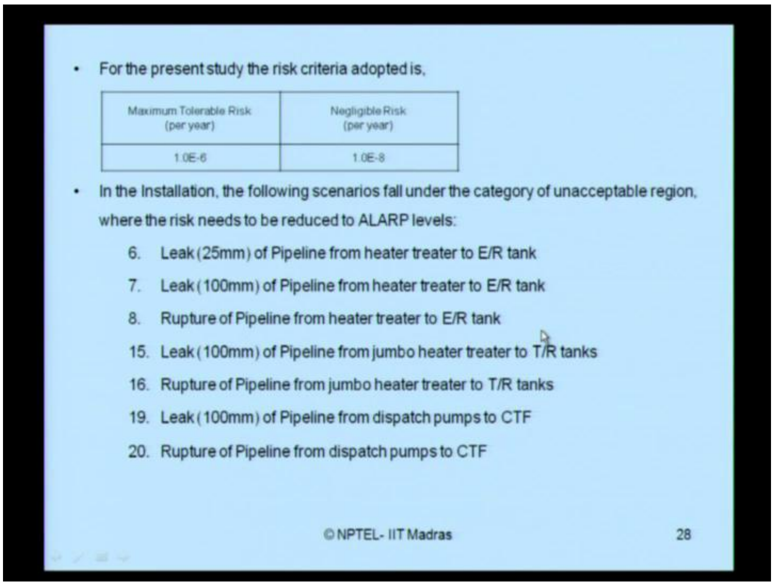

So, the maximum tolerable risk per year is about one point zero ten power minus six.And the negligible risk per year is about one point zero ten to power minus eight.This is what, I got from the present study.In the installation the following scenarios fall under the category of unacceptable region.Leak of 25 mm pipeline from heater treater to E R tank.Leak of 100 mm leak of diameter of the pipeline of eight inches dia in the same segment, rupture of the pipeline, then leak of the pipeline from jumbo heater treater to T R tanks.Rupture of the pipeline in the same segment then leak of the pipeline from dispatch pumps to CTF and rupture of the pipeline from dispatch pump to CTF.These are all the scenarios which Ihave given as specific number of six, seven, eight,fifteen, sixteen depending upon the serial number of what you analyzed in the previous slide.

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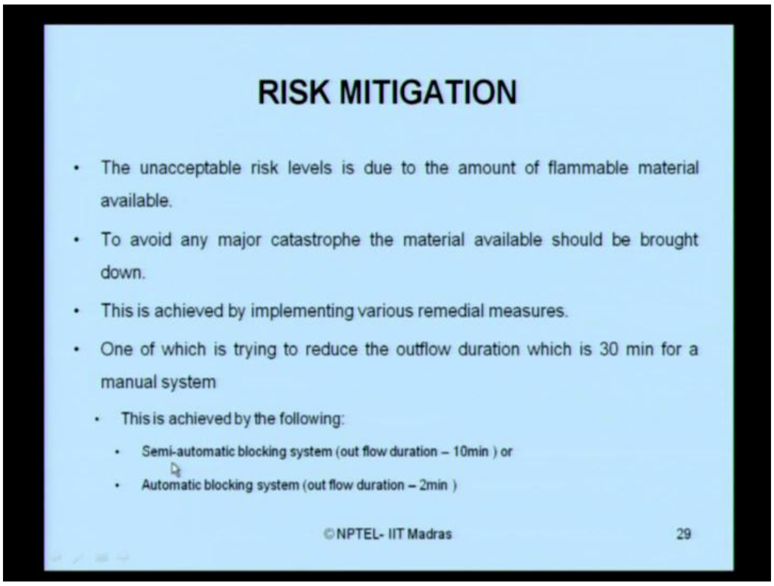

Once I get this, I will talk about what is called risk mitigation.The unacceptable risk levelis basically due to the amount of flammable material available.So, our job is to avoid any major catastrophe. So, that the material available should be brought down.This can be easily achieved by implementing various remedial measures.One of which is being tried in the specific example is outflow duration as you remember the control mechanism what i have is operatable for about 30 minute, because it is a manual system.So, what I have recommending for the specific case is either use a semi automatic blocking system which can control the outward duration to ten minute or use a complete automatic blocking system which can control out flow duration to about two minutes.What is it mean in case of any rupture, if I am using a manual system to control that mechanism.

The outflow duration will be about 30 minutes. So, there is a extensive delayin controlling that particular mitigation.If I use a semi automatic,I can control the disaster in 10 minutes.If I use an automatic,I can use the control mechanism in less than two minutes.Remember that what have a control mechanism you have in a system.You have got to give weightage in analysis for what we call as the blocking system.If you remember, I have given this weighted 0.99.For example, if I use an automatic system then I could have given as 0.1 or I got a given as 0.05.As a number is higher, it indicates me that the system is more manual and less automatic and the flow duration is very, very high.

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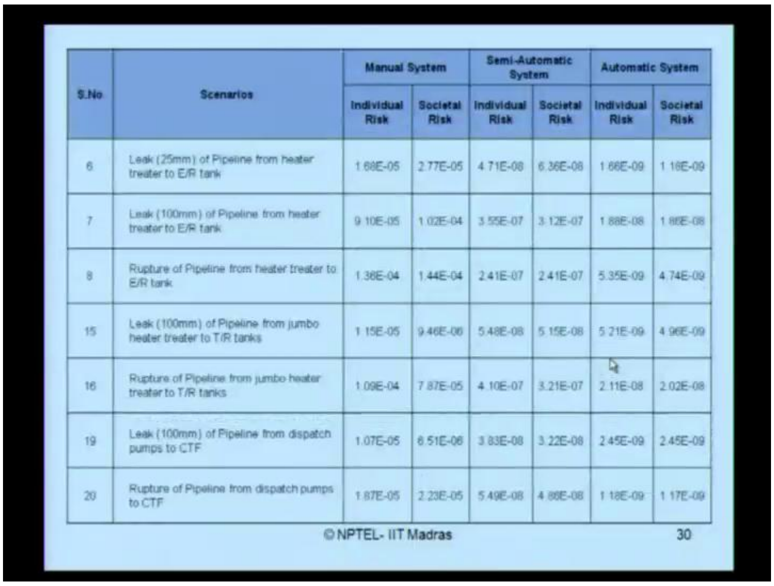

S.No	Scenarios	Manual System		Semi-Automatic System		Automatic System	
		Individual Risk	Societal Risk	Individual Risk	Societal Risk	Individual Risk	Societal Risk
6	Leak (25mm) of Pipeline from heater treater to E/R tank	1.68E-05	2.77E-05	4.71E-08	6.36E-08	1.66E-09	1.16E-09
7	Leak (100mm) of Pipeline from heater treater to E/R tank	9.10E-05	1.02E-04	3.55E-07	3.12E-07	1.88E-08	1.86E-08
8	Rupture of Pipeline from heater treater to E/R tank	1.38E-04	1.44E-04	2.41E-07	2.41E-07	5.35E-09	4.74E-09
15	Leak (100mm) of Pipeline from jumbo heater treater to T/R tanks	1.15E-05	9.46E-06	5.48E-08	5.15E-08	5.21E-09	4.96E-09
16	Rupture of Pipeline from jumbo heater treater to T/R tanks	1.09E-04	7.87E-05	4.10E-07	3.21E-07	2.11E-08	2.02E-08
19	Leak (100mm) of Pipeline from dispatch pumps to CTF	1.07E-05	6.51E-06	3.83E-08	3.22E-08	2.45E-09	2.45E-09
20	Rupture of Pipeline from dispatch pumps to CTF	1.87E-05	2.23E-05	5.49E-08	4.88E-08	1.18E-09	1.17E-09

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Once I do that then I get for different system.The manual system as a risk level for individual or societal as this.If I implement semi automatic,I will get individual and societal risk as this.If I implement completely automatic system, I get individual and societal risk as this.You can very easily see for all those identified scenarios.You will see by implementing semi automatic or an automatic from the manual system.The risk level for individual as well societal is greatly reduced.From 10 to power minus 5, it has gone to 10 to power minus 9.So, this is how we simply do a quantitative risk assessment for a simple case study of a group gathering station which is demonstrated for you.

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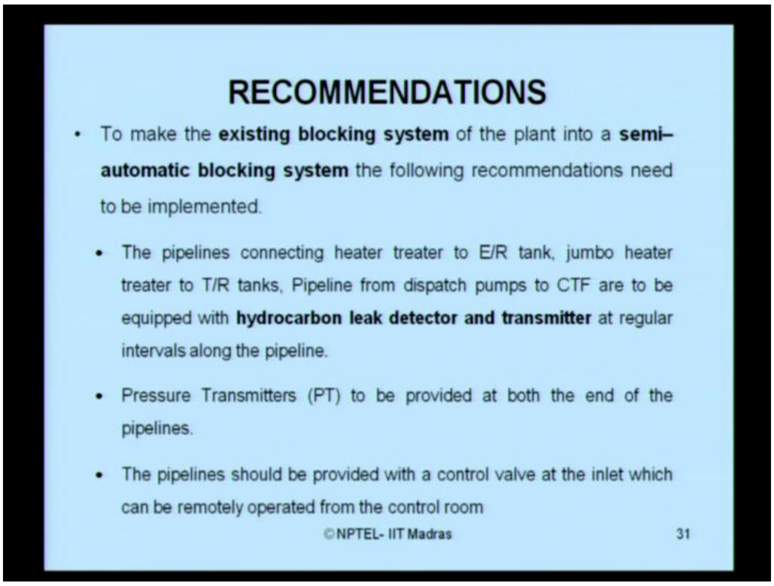

There are the following recommendations we can make for this problem.To make the existing blocking system of the plant into either a semi automatic system then in that case follow the regulations as.The pipelines connecting heater treater jumbo heater treater and pipeline a dispatched CTF are to be equipped with hydrocarbon leak detector and transmitter that is what we call a semi automatic blocking system.Because this detector will pass on information to the control room and then the control valves can be triggered off to operate and control.

So, it takes ten minutes for example, to do this operation effective.We can also recommend installation of pressure transmitter at both ends of the pipeline.We can also recommend the pipeline should be provided with the control valve at the inlet which can be remotely operated from the control room of the whole plant.

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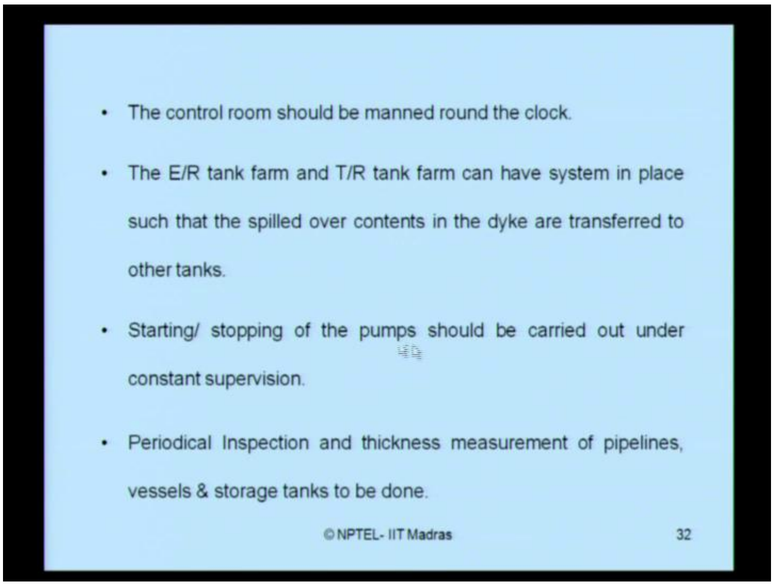

The control room should be manned round the clock.The emulsion recipient tank and the T Rtank can have system in place such that the spilled over contents in the dyke are transferred to other tank instantaneously.The starting and stopping of the pumps should be carried out under constant supervision.There should be a periodical inspection and thickness measurement on the pipeline deposits and vessels to know what kind of process scenario is happening.

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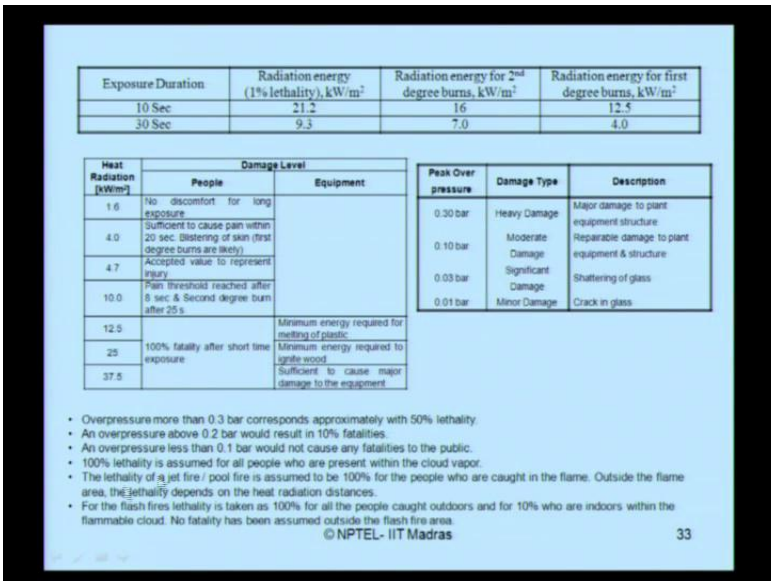

Once I do that I havea summary sheet here.If I say for exposure duration 10 seconds and 30 seconds for radiation level of one lethality of 21.2and 9.3, for radiation level of second degree burns then it is about 16 and 7.For radiation, level of first degree burns 12.5 and 4.The heat radiation varying from 1.6 to 37.5 will have a different damage level on the people.For 1.6 generally no discomfort is being given to the public.For about 12.5 on words there is an hundred percent fatality even for a short time exposure.

So, the equipment what we can use to control them the minimum energy required for melting of plastic is what you have got to do.The minimum energy required to ignite wood.Sufficient quantity to use major accident to the equipment.The peak over pressure varying from 0.3 to 0.01 in the problem will cause the damage type from heavy damage to a minor damage.The minor damage can causea crack in glass can be seen like that.The heavy damage can be seen as a major disaster to the plant equipment structure.So, this is the final summary what you will get as a recommendation and in the graphical format for a QRA.

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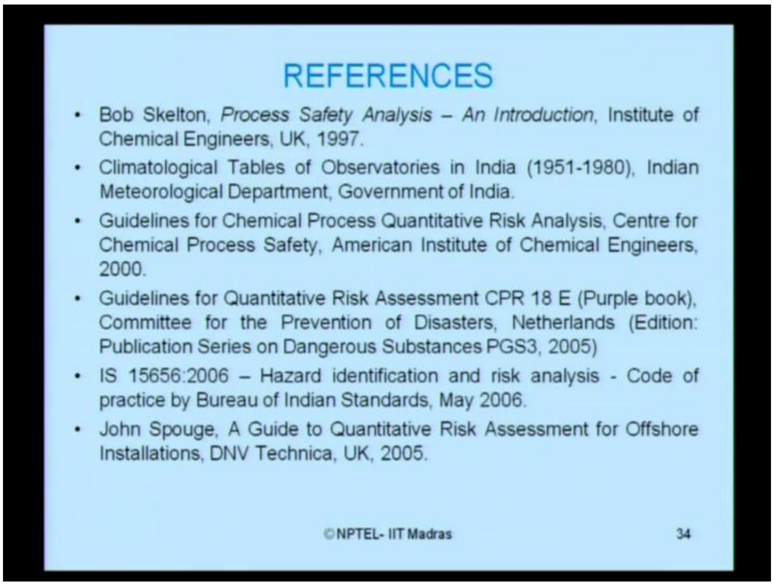

So, ladies and gentlemen, we have completed a QRA study for a specific example and Ihave given some new list of references for your future reading. And all these are very interesting available in the literature as open source as well as on the chargeable basis.Kindly go through them in detail try to identify and practice a QRA for your segment.And that will be the success listening to this lecture.If you have any questions, we are happy to post it at NPTEL,IIT madras.

Thanks.